# ACOUSTICAL CEILING DIFFUSOR

This Application claims the benefit of US Provisional Application 60/463823 filed April 18, 2003.

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates to acoustical listening environments. Specifically, the present invention relates to an acoustical ceiling diffuser than can be retrofit into an existing ceiling without adversely affecting ceiling height.

### Description of Related Art

In an acoustical listening environment there is the need for absorption and diffusion. Absorption is very easily accomplished, but diffusion not so much so. In order to achieve the necessary diffusion for an appropriate sound field, the diffusers are often large, cumbersome, and frequently unattractive.

One of the problem areas is the need for diffusion on the ceiling. Having proper diffusion on the ceiling offers the following benefits:

1. It breaks the first reflection point from the listener to the speaker at broader bandwidths than purely absorption.
2. It does not overly attenuate the high frequencies.
3. It increases spaciousness in terms of the sound field. The room and ceiling height will sound larger and higher than what is actually there by balancing reverberation times throughout the frequency spectrum, particularly the mid range.
4. It breaks up the room mode caused by the parallel nature of the floor to the ceiling. However, the diffuser must cover a large area of the ceiling to be effective for this point.

Conventional diffusers, depending on well spacing and bandwidth desired can be 12 inches deep or even deeper. Many people who enjoy music set up listening rooms in the basement or other less used parts of the house. Because these rooms typically were not originally designed to be used for this purpose, they often have low ceilings. If a ceiling is low, one can not add a conventional diffuser without adversely affecting the ceiling height. Thus, many listening rooms do not have the luxury of including a conventional diffuser.

Thus, there is a need for a diffuser that can be used in a space having a low ceiling. There is also a need for a system which allows the user to add absorption along with diffusion.

There is a need for a cost effective, easy to install ceiling diffuser. There is a need for a ceiling diffuser which can be retrofit into an existing ceiling. There is also a need for a ceiling diffuser which can be quickly installed.

## SUMMARY OF THE INVENTION

The present invention is a ceiling diffuser that can be retrofit into an existing ceiling by installing the inventive diffuser between the existing joists and covering the ceiling with scrim wrap or other acoustically transparent material.

In one embodiment, the ceiling diffuser of the present invention is coupled with sound absorption. A layered structure is installed between the joists. The structure comprises a layer of insulation, a layer of sheetrock, a layer of sound deadening material, a layer of high frequency sound absorptive material and a layer of angled blocks. Preferably, the layered structure is enclosed on three sides by a frame. In the preferred embodiment, the angled blocks are formed integrally with the frame. In an alternative embodiment, the frame houses the angled blocks. The frame including the diffuser can then be installed between the joists. Preferably, the ceiling is covered by an acoustically neutral fabric.

In the preferred embodiment, the speakers to be used with the system are placed parallel with the joists.

A virtual perpendicular centerline of the room intersects the joists. The angled blocks come together in a "V" or inverted "V" at the centerline. The angled pattern is reversed between successive joists. Thus, between every other joist pair the blocks either all angle toward the bearing wall or all away from the bearing wall. The resulting pattern is symmetrical on the right and left side of a virtual centerline.

By mounting the ceiling diffuser between the joists, it accomplishes the following goals:

1. It takes up essentially no space in terms of ceiling height.

2. The angled pattern offers directionality (or wave guide transmission) of the diffusion.

3. It offers ample bandwidth going from approximately 350 Hz up to 2 kHz with diffusion coefficients of approximately 0.35 to 0.70

4. It offers absorption at high frequencies from 2k to 20k with absorption coefficients of approximately 0.5 to 0.9.

5. It is aesthetically pleasing as it is covered with scrim wrap or other acoustically transparent fabric, and thus appears as a cloth covered ceiling.

## BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a cross section of a ceiling with the inventive diffuser installed between the joists.

Figure 2 shows a cross section of a diffusing panel along line II-II of Figure 1.

Figure 3 is a cross section of the inventive ceiling diffuser.

Figure 4 is a schematic view of a listening room.

Figure 5 is a cross section of a series of panels installed to angle away from the walls.

Figure 6 is a cross section of a series of panels installed to angle toward the walls.

Figure 7 is a bottom view of the diffuser installed between the joists.

Figure 8 is a top view of the diffuser installed between the joists.

Figure 9 is an end view of a panel.

## DETAILED DESCRIPTION

A ceiling 10 typically comprises of a sub-floor 14 from the floor above and a series of parallel joists 12. The joists 12 rest on bearing walls (not shown) and are typically made of 2 x 10 wood boards. The depth and spacing of the joists 12 may be dictated by engineering requirements, local building code or design choice. In most homes, the ceiling joists 12 are about 16 inches apart and about 10 inches deep. The present invention is a diffuser 50 that can be built into a ceiling between the joists 12.

While, the inventive diffuser 50 is especially useful in rooms 30 with low ceilings 10, the inventive diffuser 50 can be used in any room 30. It is not necessary that the room 30 have a low ceiling 10, nor is it necessary that there be a sub-floor 14 above.

In one embodiment, the diffuser 50 is combined with absorption and a layered structure installed between the joists 12. In a first preferred embodiment, a diffuser is installed between the joists 12. The first layer is a layer of insulating material 18. Preferably, the insulating material is Fiberglass batt insulation. The next layer is a layer of sheetrock 20. The sheetrock is attached to the joists 12 using blocks 16. Typically, the block is a 2 inch by choice board and is run the length of the joist 12. The sheetrock 20 is attached to the block 16. Next a layer of sound deadening material 22 is laid. Preferably, one half-inch sound deadening board 22 such as Celotex is used. A second layer of sheetrock 20 is then laid. Preferably, the sheetrock 20 layers use 5/8 inch sheetrock. Next a high frequency sound absorptive material 26 is laid between

the joists 12. Preferably, a semi-rigid pressed fiberglass board is used for the sound absorptive material 26 as the rigidity of the board makes it easy to install.

The next layer is a plurality of angled paddles 24. The paddles 24 are made of wood, plastic or other known material. The paddles 24 are installed at an angle $\alpha$. Preferably, the paddles 24 are angled 15° and 40° from horizontal. More preferably, the paddles are angled 30°-35°. Most preferably, the paddles are angles 35°.

Preferably, one paddle 24 is attached directly over the area where the previous paddle 24 ends. The paddles 24 are individually installed between the joists 12 or one or more paddles 24 may be attached as part of a preformed unit. The paddles 24 are angled in a symmetrical pattern about an imaginary centerline 42 perpendicular to the joists 12. Between each successive pair of joists 12, the pattern reverses with the paddles 24 angled toward the centerline 42 between one pair of joists 12 and away from the centerline 42 between the next pair of joists 12.

It is preferable that the diffuser 50 subtract less than 2 inches from the ceiling 10 height. More preferably, the diffuse 50 subtracts less than 1 inch from the ceiling 10 height. Most preferably, the diffuser 50 does not reduce the ceiling 10 height.

The finished ceiling 10 with the diffuser 50 is covered with an acoustically neutral material 28 such as scrim wrap. Preferably the material 28 is stretched over a frame 32, such as a frame made of pine or other wood and panels are installed. Preferably, the diffuser 50 is installed between the joists and the frame is installed on top of the joists.

Figures 1 and 2 show a cross section of a ceiling with the inventive diffuser 50 with absorption installed between the joists 12. The angled paddles 24 are made of a standard blocking material installed within the joists 12 and are angled between 15°-40° from horizontal. The preferred angle is 30°-35°. The degree of angulation has a small effect of the bandwidth.

The angled pattern shown is reversed in every other cavities 44 between the joists 12. In every cavity the panels are either all angled toward or all away from the bearing walls. The centerline 42 of the room 30 is where the angled panels come together to form a "V" or an inverted "V". Thus, the pattern is symmetrical on the left side and right side of the virtual centerline 42 of the listening room 30, and provides a symmetrical diffusion pattern.

Figure 3 shows a cross section of a diffusing panel 50. In a second preferred embodiment, a pre-fabricated diffusing element 52 is used. The diffusing element is easy to install. The system may be installed for an entire

ceiling 10 in a matter of a few hours. The diffusing elements 52 are reversible and thus can go in either direction and create the alternating "V" and inverted "V" patterns as desired. Preferably, each element 52 is about 4 feet long and can be cut into shorter lengths, preferably 1-foot lengths. This allows the system to be adapted to just about any room 30 or ceiling 10. Preferably, the diffusing element 52 comprises a frame 54 with angled paddles 56.

Preferably, the paddles 56 are pre-formed. Preferably, a U-shaped or three-sided frame 54 with a plurality of angled paddles 56 is used. However, other shaped frames 54 could be used such as a flat base from which the paddles project or an open frame. The paddles 56 and the frame 54 can be made from the same or different materials. Preferably, the frame 54 and paddles 56 are made of a rigid non-absorptive or minimally absorptive material. In another preferred embodiment, the frame 54 and paddles 56 are made of a rigid semi-absorptive material. For example, the paddles 56 and/or frame 54 could be made of wood, plastic or other known material. In an alternative embodiment, the frame 54 and/or paddles 56 could be a laminated structure. In an alternative embodiment, a portion of the frame 54 is made of or is laminated to a sound absorptive and/or sound isolation material. It is also preferable that the frame 54 is made of a non-resonating material. The thickness of the frame 54 can be adjusted to limit resonance or preferably a material with different resonant properties than the frame could be laminated or adhered to the frame. Preferably, the diffusing element 52 is vacuum molded. Alternatively, they could be injection molded or molded using any known technique.

Preferably, the paddles 56 are formed integrally with the frame 54. Alternatively, the paddles 56 could be attached to the frame 54. In one alternative embodiment, the frame would have a series of apertures (not shown) and the paddles 56 would have cooperating projections (not shown). In yet another embodiment, the paddles 56 could be affixed to the frame with adhesive or other known attachment means such as nails or bolts.

Preferably, the diffusing element 52 is made in four-foot lengths and the angled paddles 56 are approximately 12 inches apart. The elements 52 could be longer or shorter. More preferably, they can be cut into shorter lengths, such as one-foot lengths with the paddles 56 placed at intervals to facilitate cutting between them. The distance between the paddles 56 can be varied with the angle of the paddles 56 and depth of the diffusing element 52. Preferably, one paddle 56 begins where the previous paddle 56 ended. This allows for the elements 52 to be cut into smaller lengths and for the elements 52 to cooperate with other elements 52. For example, for a 4-foot element 52 with paddles 56

placed at 1 foot intervals could be cut into 1, 2 or 3-foot lengths. Element 52 could be cut as needed to complete the room 30.

Preferably, the paddles 56 are angled 15°-40° from horizontal. More preferably, they are angled 30°-35°.

The typical ceiling joist 12 is 10 inches deep. Preferably, the diffusing element 52 has a depth of at least 4 inches. More preferably, the diffusing element 52 has a depth of approximately 4-5 inches. Most preferably, the diffusing element 52 has a depth of about 5 inches. The deeper the diffusing element 52, the more diffusion. In an alternative embodiment, the diffuser has a depth of 8 inches.

Most preferably, the diffusing element 52 is about 4 feet long, about 14 1/2 inches wide, has a depth of approximately 5 inches, and angled paddles 56 approximately 12 inches apart with an angle $\alpha$ of about 35° from horizontal. However, the diffusing element 56 can be any size shaped to fit between the ceiling joists 12.

In one embodiment, the diffusing element is combined with absorptive material 26 and/or sound isolation material 22, and the layer element 56 is fit between the joists 12 so as to not adversely impact ceiling height. Preferably, reducing the ceiling 10 height by less than one inch.

The pre-formed diffusion elements 52 could be stapled to the ceiling 10 between the joists 12. Alternatively, other known attachment methods could be used such as adhesive, nails, etc., to attach the diffusion elements 52 to the ceiling. Preferably, the diffusion element 52 is attached to the joist 12. In the preferred embodiment, it is not necessary to isolate the diffusers 50 from the joist 12 or from any sub-floor 14 or roof (not shown).

The diffusion elements 52 are installed in the cavity between a pair of joists 12 from the virtual centerline 24 toward the walls (not shown). One element 50 is placed on each side of the virtual centerline 24 to form the "V" or inverted "V". The next element 52 is installed with the paddles 56 angled in the same direction as the adjacent element. Each element 52 is installed with the paddles 56 angled in the same direction as the adjacent element 52. In the next cavity, the paddles 56 will be angled in the opposite direction.

In an alternative embodiment, the diffusing element 52 could be used in conjunction with absorptive material 26 and/or material for sound isolation 22. The absorbtive and/or sound isolation material could be installed between the joists 12 and then the elements 52 installed. In another embodiment, the diffusing element could have absorptive material and/or sound isolation material

laminated to the frame. For example, fiberglass batting or other material could be attached to the base of the frame.

Scrim wrap or other acoustically neutral material 28 could be placed on each diffusing element 52. Alternatively, acoustically neutral material 28 could be stretched to cover the entire ceiling 10 at one time. In yet another embodiment, the material 28 is stretched on frames 32 that are then attached to the ceiling 10.

The preferred diffuser 50, 52 makes use of diffusion and has wave guide properties. This is the preferred system when the speakers 34 of a sound system are aligned parallel with the joists 12. In other rooms, where that configuration for the sound system is impossible or undesirable (for aesthetic, room flow, or other reasons) a quadratic diffuser or other type of diffuser could be adapted to be fit between the joists 12. The ceiling would then be covered with the scrim wrap or other acoustically neutral material 28.